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Assessment of Permanent Passive Stack Ventilation for Delhi Region, India

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Abstract: **Passive ventilation is a function of a driven force of wind and buoyancy; it also works as a passive cooling driven by natural wind with thermally generated pressure. It has an appropriate consistency and can provide cleaner air with low maintenance along with reduced cost and carbon emission. This paper deals to provide appropriate permanent passive ventilation to different functional spaces of the residence through Normalization of loop analysis to size the openings, slits, stack vents, and cut-outs for better ventilation as desired. The normalized equation for Passive Stack ventilation model which is applied for a case of single and double storied residence in Gurgaon, 64 DLF phase 2, Delhi, India. Each space in the residence – Bed rooms, living etc., would demand a different no.of air changes with respect to their occupancy and volume. It is found that the requisite permanent ventilation required for Living room is 15840 sq.mm Stack cross sectional area and 4070 sq.mm Slit window area, for Dining room is 16000 sq.mm Stack cross sectional area and 11890 sq.mm Slit window area, for Bedroom is 4503 sq.mm Stack cross sectional area and 3490 sq.mm Slit window area, for Toilet is 2060 sq.mm Stack cross sectional area and 1803.8 sq.mm Slit window area, for Kitchen is 16700 sq.mm Stack cross sectional area and 4290 sq.mm Slit window area during hot climate for double floor Stack model. And the requisite permanent ventilation required for Living room is 2220 sq.mm Stack cross sectional area and 9600 sq.mm Slit window area, for Dining room is 11400 sq.mm Stack cross sectional area and 9600 sq.mm Slit window area, for Bedroom is 3800 sq.mm Stack cross sectional area and 3130 sq.mm Slit window area, for Toilet is 5510 sq.mm Stack cross sectional area and 3070 sq.mm Slit window area, for Kitchen is 2340 sq.mm Stack cross sectional area and 2070 sq.mm Slit window area during hot climate for single floor Stack model. Similarly, it is found that the requisite permanent ventilation required for Living room is 9040 mm^2Stack cross sectional area and 5820mm^2 Slit window area, for Dining room is 16000 mm^2Stack cross sectional area and 14300mm^2 Slit window area, for Bedroom is 5000 mm^2Stack cross sectional area and 4470 sq.mm Slit window area, for Toilet is 2171 mm^2 Stack cross sectional area and 2065 m^2Slit window area, for Kitchen is 9530 sq.mm Stack cross sectional area and 6131 mm^2 sq.mm Slit window area during cold climate for double floor Stack model. Because of the moralization, as per the standards and context, areas have been evolved with respect to the carpet area and volume meant for a maximum of 5 to 7 persons. The proposal may also satisfy the proposed standards of US ventilation standards – Standards of 1964, which apparently the basic guiding yard stick to the standards and norms developed for ventilation requirement thereafter.**

Keywords: **Permanent ventilation, Thermal buoyancy, pressure gradient, indoor environment, Stack effect, Normalization technique, Solar Chimneys.**

I. INTRODUCTION

One of humanity's most threatening phenomenon is global warming; its major cause is CO_2 emissions originating from fossil fuels consumption. Buildings' consumption of energy is responsible for about 40% of the total world CO_2 emissions, in which space heating, ventilation and air conditioning are the major consumers with more than 60% of the total building services' consumption. This is why it's vital to search for alternative methods that are more environment friendly and cost less on the energy bill. Ventilation affects greatly health, productivity and comfort of occupants, and thus it's significant to try to optimize it and search for green alternatives and creative solutions that are both environment conducive and effective in improving indoor air quality and thermal comfort. Passive Stack Ventilation improves the indoor air quality and plays a major role fighting against air pollution, which is among the top five environmental health risks, for people spend on an average 80–90% of their time inside buildings and closed environment, therefore it is very important to maintain the indoor environment in a good quality. Passive ventilation operates with natural means of ventilation that makes use of natural forces, such as wind and thermal buoyancy, to circulate air to and fro of an indoor space. These ventilation systems work to regulate the indoor air temperature as well as to bring fresh air in to the building in a passive means to drive out stale air. Most of the buildings can make use of PSV systems including residences, office buildings, school, theatres, and hospitals for cost effective, low maintenance, fresh air and steadiness to some extent, reduce carbon emissions. Passive ventilation doesn't require conventional or non-conventional energy to operate the system, so it saves energy and cut down on carbon emissions. PSV is a way of extracting hot air from a building through the 'stack effect'. The stack effect according to Liddament [20] results from the differences in air temperatures between the exterior and the interior of a building creating a vertical air density difference within the building.

A higher internal temperature causes air to flow into the building through lower fenestrations of the building and exit through upper openings of the building [13]. This supplies fresh air while driving out foul air [7]. From literature, the principle of stack ventilation has been traced to the ancient ages [13], [21]. Coles and Jackson [1] posits that the early man of the Minoan period prompted upright air flow through wind towers and the building height. Between 4000-5000BC, Chinese rural villages of Banpo used chimneys to extract smoke from their homes [2] while the Anasazi Pueblo Kiva used aeration chutes with top outlet vents [12]. Vent holes have also been found on the flat roofs of buildings from the Roman Empire periods [24].

The House of Commons in England and the American house represent the 19th century application of the principle [9] where open fires (kiln-vents) and exhaust vents were used to create a thermal draft [8]. Today, the strategy adopts modern techniques while heavily relying on the traditional basic precept of the chimney stack [13]. Research and technology has over time been incorporated in the strategy to increase its efficiency even in regions with low internal-external temperature variances. The advanced modifications that utilize the sun and wind have given rise to solar induced, wind-stack driven and fan induced stack ventilation mechanisms [21]. Solar induced ventilation relies on heating the building fabric (solar chimney, solar roof and double facades) [14] by the sun to create temperature differences [3], [21]. Examples of buildings with solar induced stack ventilation include the BRE Environmental offices in Watford [19] and the McCann Fitzgerald Offices in Dublin [1]. Studies and practice have shown that wind can also assist in stack ventilation by use of wind catchers, cowls or wind towers [10], [18], [25]. This technique is known as wind-stack driven or wind assisted ventilation [21] and is applied in the IONICA Building in UK [22]. Fan induced stack ventilation is installed to improve natural stack ventilation's reliability and efficiency especially in hot-humid regions where natural driven ventilation is insufficient [19]. This is done through the use of either mains powered or solar powered fans [11]. It has been observed in the literature that the preliminary estimates may then be used to compute estimates of ventilation system component sizing by using the loop equation design method [4] – after the building designer selects an appropriate system configuration and topology [15]. Survey based analysis conducted and were administered in five Indian cities selected as representative locations for the five climate zones in India and documented in order to understand thermal and ventilation conditions in five cities during summer, winter and monsoon seasons [23]. Thermal comfort in terms of thermal buoyancy has been addressed through solar thermal model to derive the indoor temperature swings in heating and cooling period in composite climatic zone [26]. Apparent air quality, Sick Building Syndrome (SBS) indicators (108 m3) in relation to ventilation with an outdoor airflow corresponding to an air change were studied in a normally furnished office space critically [27]. This paper discusses about Passive stack Ventilation without the use of any mechanical inputs through the normalization loop analysis for single and double floor residential buildings of row type built form where lint and ventilation draw from front and rear side of the building blocks in composite climatic zone of India.

II. LOOP EQUATION MODEL

Loop equations are applied to size the passive ventilation system components with respect to the free area of a ventilation openings and its configuration of ventilation system, the design requirements, and the design conditions. A number of manual and simple computational tools may achieve this objective but only partially. Most of the Models are based on simplistic single-zone models of building systems that, most often, ignore the relatively complex problem of coupled thermal/airflow behaviour, some are limited to specific climates, and few account for internal resistances to ventilation airflows. One approach, the inverse solution method presented by [17] has, however, been generalized to create the loop equation design method [5], [6] that provides the means to size internal as well as envelope components of multi-zone ventilation systems of arbitrary configuration and complexity for specific climatic conditions.

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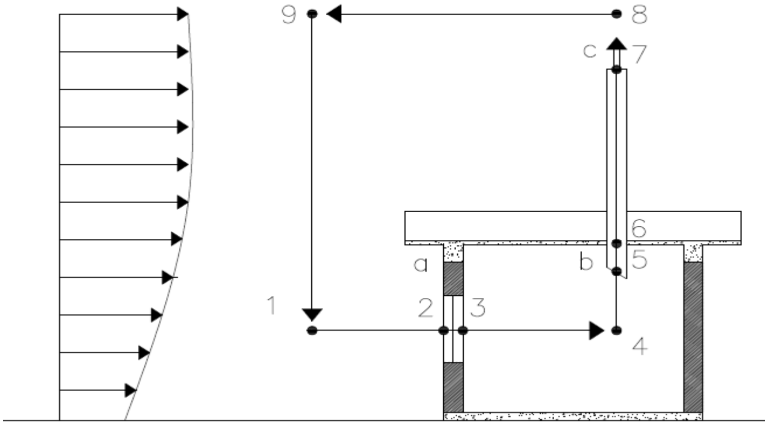

FIGURE 1: PRESSURE DROPS ASSOCIATED WITH BUOYANCY-DRIVEN STACK VENTILATION FOR SINGLE BUILDING MODULE

The sizing of components of natural ventilation systems [16], [17] derived based on the methods of network airflow analysis through buoyancy driven concepts to formulate a simplified loop equations with respect to ACHs, temperature and reference wind speed in the literature. Accordingly the same has been adopted for studying and assessing PSV for a single floor building, double floor building and double height building in DLF Phase II, Delhi region. The buoyancy driven stack/ passive Ventilation system of normalization method is given below showing the simple loop equation for a single-zone building model [6] and the same as shown in the Fig.1.

The equation (1) indicates the pressure drops ΔP_l, that is the summation of hydrostatic changes ΔP_s, and 'windward and leeward pressures' changes $\Delta P w$,

$$\Delta P_l = \Delta Ps + \Delta P_w \qquad [1]$$

$$C_{P2}(\rho_o U_{ref}^2)/2 - \Delta P_a - \rho_i g \Delta z_{4,5} - \Delta P_b - \Delta P_{b,c} - \rho_s g \Delta z_{5,8} - \Delta P_c - C_{P8}(\rho_s U_{ref}^2)/2 + \rho_o g \Delta z_{9,1} = 0 \qquad [2]$$

$$\Delta P_e = \rho Q_e^2 / 2 C_d^2 A_e^2 \text{, for larger openings, where } \Phi_e = A_e \qquad [3]$$

$$\Delta P_e = \frac{fL}{2} (\rho Q_e^2 / D_h A_e^2) \text{, for flow in ducts, where } \Phi_e = D_h A_e^2 \qquad [4]$$

Where,

C_d = Discharge coefficient, ρ = Density, Q = Volumetric air flow rate, A = Area of the opening, g = acceleration due to gravity, Δz_{ij} = Elevation change from 'i' to 'j' (i, j are loop points, i, j = 1-9), C_p= Pressure coefficients, U_{ref} = Reference wind speed, L = Length of the duct, D_h = Hydraulic diameter, f = friction factor.

III. CASE STUDY OF 16 K, DLF PHASE II AND RESULTS

A Case study of Residence has been considered in composite climatic region, 16K DLF phase 2, Gurgaon, Delhi Capital region, India (28.483609 Latitude, 77.081330 Longitude). The typology is row housing i.e., having a possibility of having opening towards the front and rare end of the building as shown in figures 2 & 3.

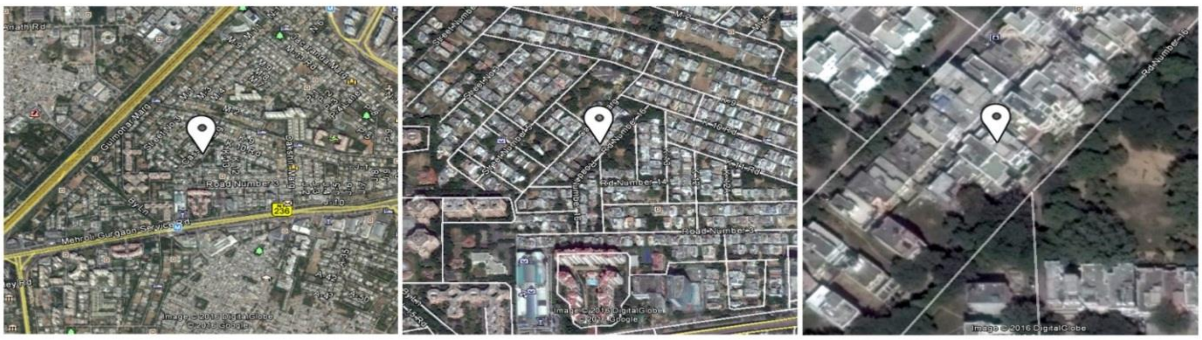

FIGURE 2: SATELLITE IMAGES SHOWING THE CASE STUDY

Designed by an Architect of the Local Body, the Duplex unit (110 sq. m in each floor) in a plot size of 10m x 20m, consists of a Living room, Dining room, Kitchen, wash area, a Master Bedroom and a stairway in the ground floor and, a hall and two bedrooms and wash areas in the ground floor as shown in figure 3.

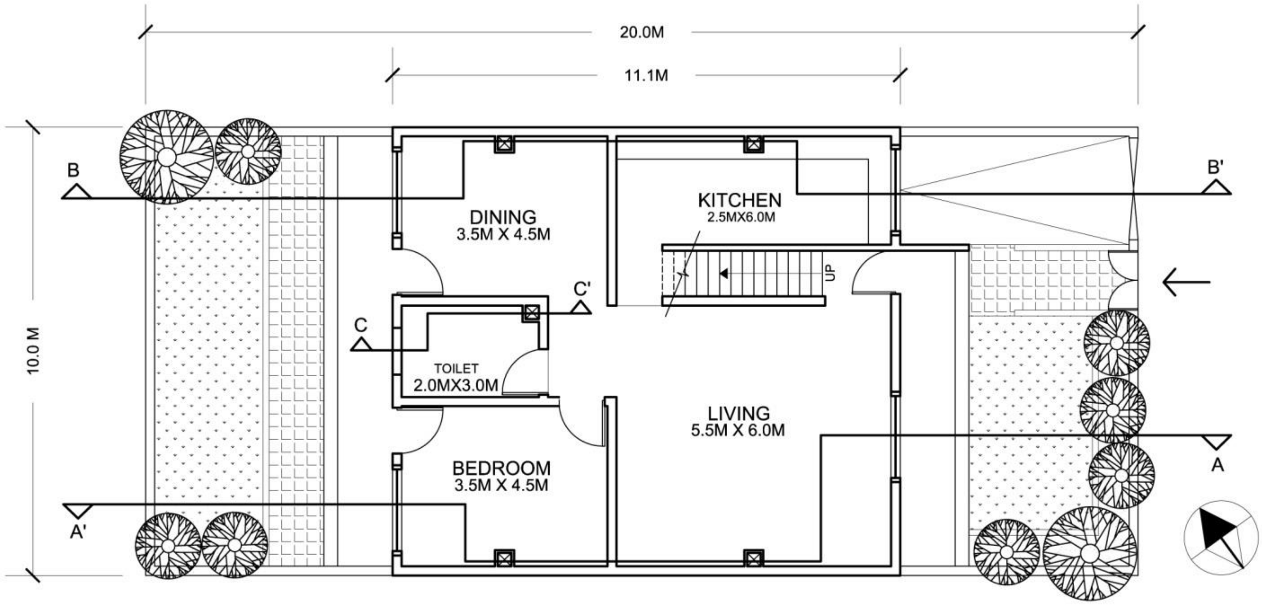

FIGURE 3 : GROUND FLOOR PLAN OF THE RESIDENCE

However, equation [2] has been applied to assess the Passive Stack ventilation for three cases:

(a) One storied residence (b) two storied residence and also for a case of (c) double height roof in Living room, as illustrated in cross sections of building as shown in figures 4-9. Each functional space in the residence – Living, Bed rooms, Kitchen and toilet etc., would demand a different rate of ACH with respect to their activity, occupancy and volume. The floor plans, cross section and normalization profile etc., have been indicated and shown in figures 4-9.

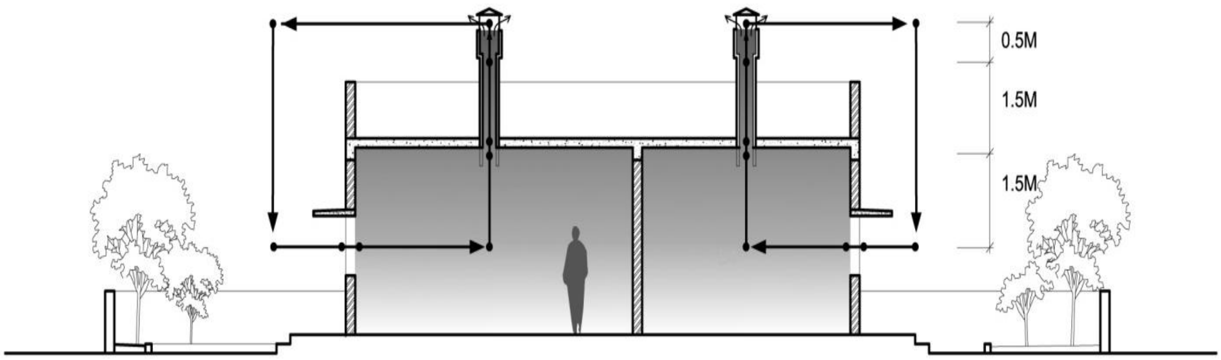

FIGURE 4 : SECTION AA' THROUGH LIVING ROOM AND BED ROOM – CASE (A)

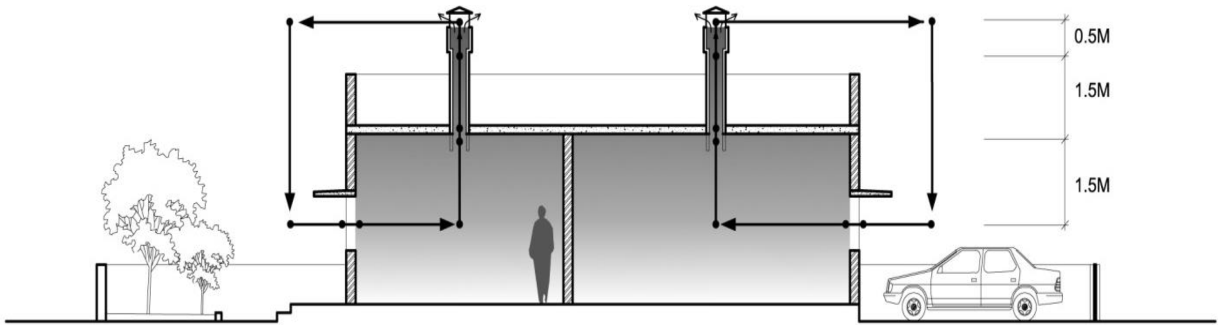

FIGURE 5 : SECTION BB' THROUGH DINING ROOM AND KITCHEN – CASE (A)

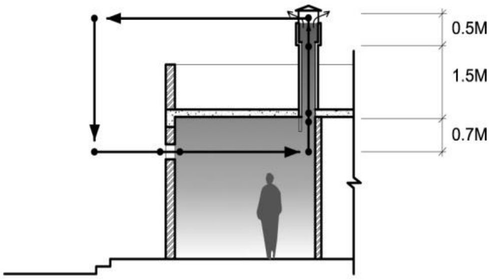

FIGURE 6 : SECTION CC' THROUGH THE TOILET – CASE (A)

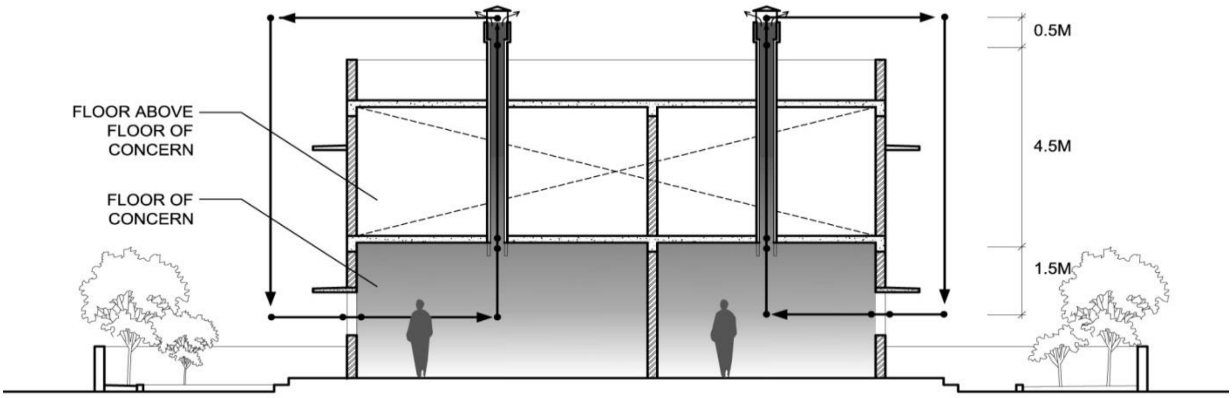

FIGURE 7 : SECTION AA’ THROUGH LIVING ROOM AND BED ROOM – CASE (B)

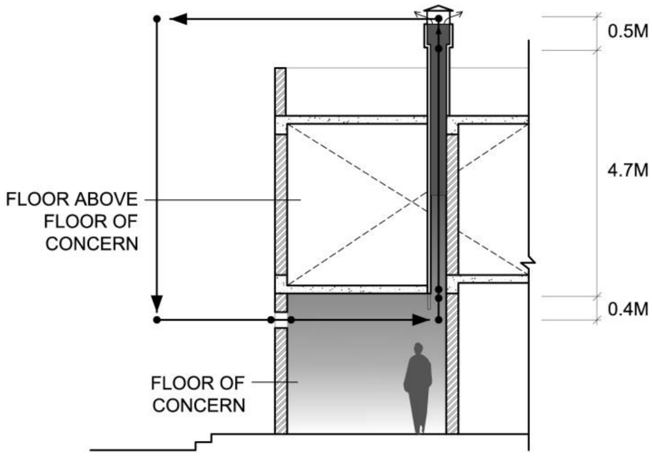

FIGURE 8 : SECTION CC' THROUGH THE TOILET WITH SUNKEN SLAB – CASE (B)

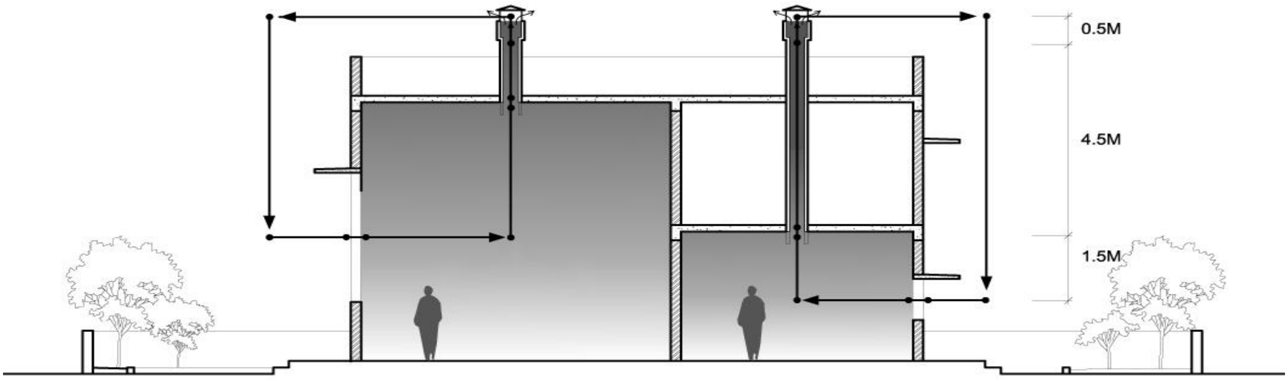

FIGURE 9 : SECTION AA’ THROUGH DOUBLE HEIGHT ROOF LIVING ROOM AND BED ROOM – CASE (C)

The cross section of the stack duct is assumed to be a square as shown below as shown in figure 10. So, the Hydraulic diameter, D_h would be equal to the side of the square. Hence, equation [4] would be

$$\Delta P_e = \frac{fL}{2} \left(\rho Q_e^2 / s^5\right) \quad [5]$$

Where,'s' is a side of the square cross section.

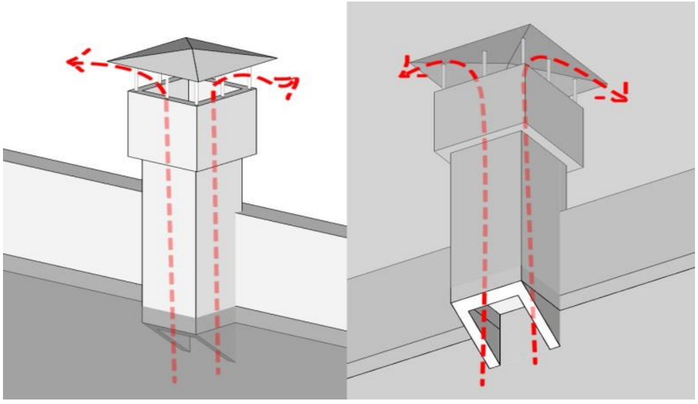

FIGURE 10 : ILLUSTRATION SHOWING STACK DUCT FROM OUTSIDE (LEFT) AND INSIDE (RIGHT)

TABLE 1: VOLUMETRIC AIR FLOW RATE (Q) W.R.T. VOLUME AND RATE OF AIR CIRCULATION FOR CASE (A)

S. no.	ROOM	Description (in sq. m)	Rate of Air circulation	Case (a)		Case (b)		Case (c)	
				VOLUME (m^3)	Volumetric air flow rate (Q_e)(m^3/sec)	VOLUME (m^3)	Volumetric air flow rate (Q_e) (m^3/sec)	VOLUME(m^3)	Volumetric air flow rate (Q_e) (m^3/sec)
1	LIVING ROOM	5.5 x 6	4.5 ACH (NBC 2005)	99	0.15	99	0.15	198	0.25
2	DINING ROOM	3.5 x 4.5	8 L/S per person (ASHRAE)**	47.25	0.048*	47.25	0.048*	47.25	0.048*
3	BED ROOM	3.5 x 4.5	3 ACH (NBC 2005)	47.25	0.04	47.25	0.04	47.25	0.04
4	TOILET	2 x 3	8 ACH (NBC 2005)	18	0.04	15.9	0.035	15.9	0.035
5	KITCHEN	2.5 x 6	15 ACH***	45	0.19	45	0.19	45	0.19

***** - Rate of air circulation for Kitchen has been assumed as 15 ACH.**

**** - Rate of air circulation has not been provided for Dining rooms in NBC 2005. Hence ASHRAE standards are considered.**

*** - The Volumetric air flow rate for dining is considered for 6 persons.**

The input variables OF the loop equation [2] have been given the table.2. The design variations or changes $\Delta z_{i,j}$ are considered as per the residential unit as shown in the figures 4-9. The outside air temperatures (T_o) are ambient hourly average temperatures taken in a 15th May for cooling period, and in 15th December for heating period. Indoor air temperatures (T_i) or indoor design temperatures, Stack air temperature in cooling period is assumed to be 8 – 10% more than the indoor air temperature and 20-25% more in heating period. The wind velocities have been considered as given by the Indian Meteorological Department, of Delhi and it is assumed that the wind is equal and constant for the applicable steady state conditions.

TABLE 2: RESPECTIVE INPUT VARIABLES IN THE EQUATION

S. no.		Cooling Period	Heating Period
1	Outside Air Temperature (T_o)	33.26 C	13.9 C
2	Outside Air density (ρ_o)	1.1548 kg/m^3	1.2386 kg/m^3
3	Inside Air Temperature (T_i)	27 C	20 C
4	Inside Air density (ρ_i)	1.177 kg/m^3	1.21 kg/m^3
5	Stack Air Temperature (T_s)	30	25
6	Stack Air density (ρ_s)	1.1666 kg/m^3	1.1868 kg/m^3

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7	**Velocity (U_{ref})**	4.1 m/s	2.3 m/s
8	**Windward pressure Coefficient (C_p)**	0.7 (IS:875-part 3, Sec. 6.2)	
9	**Stack Terminal pressure Coefficient (C_p)**	-0.5	
10	**friction (f)**	0.03	
11	**Discharge coefficient (C_d)**	0.6	
12	**Length of the duct (L)**	1.5M for Single floor stack	
		4.5M for double floor stack	
13	**Acceleration due to gravity (g)**	9.8 m/s2	

IV. RESULTS

The equation [2] has been evaluated for Living room in Case (a) during heating period to obtain the areas of openings through the following equation:

$$(0.038/A_a^2) + (0.038/A_b^2) + (0.038/A_c^2) + (0.0006/s^5) = 1.44 + 3.86 \quad [6]$$

where 'A_a' is the area of the window, 'A_b' is the area of the room outlet, 'A_c' is the area of the stack terminal, 's' is side length of the square cross-sectional duct, 1.44 is the hydrostatic pressure (P_s) and 3.86 is the wind pressure (P_w). Considering cases where all design parameters are allowed to approach large values, the window inlet vent has been evaluated.

$$(0.038/A_a^2) = 1.44 + 3.86, \text{ with wind case} \quad [7]$$

$$(0.038/A_a^2) = 1.44, \text{ with-out wind case} \quad [8]$$

Hence, the area of the window has to be more than 0.16 sq. m for without wind case, and more than 0.08 sq. m for with wind case. Similarly, the side can also be determined as 0.4m for with wind case and 0.3m for without wind case. In the same way, equations are worked out for different cases and the results are given in the table 3.

TABLE 3: VARYING OPENINGS AND DUCT SIZING FOR HEATING AND COOLING PERIODS

	Heating Period				**Cooling Period**			
	With wind		**Without wind**		**With wind**		**Without wind**	
	Min. area of a window (in sq.m)	Side length of a square cross-sectional duct (s) in m	Min. area of a window (in sq. m)	Side length of a square cross-sectional duct (s) in m	Min. area of a window (in sq. m)	Side length of a square cross-sectional duct (s) in m	Min. area of a window (in sq.m)	Side length of a square cross-sectional duct (s) in m
Case (a)								
Living	0.085	0.163	0.164	0.211	0.057	0.140	-	-
Dining	0.027	0.103	0.053	0.134	0.018	0.089	-	-
Bedroom	0.023	0.096	0.044	0.124	0.015	0.082	-	-
Toilet	0.023	0.096	0.044	0.124	0.015	0.082	-	-
Kitchen	0.108	0.179	0.208	0.232	0.072	0.153	-	-
Case (b)								
Living	0.075	0.192	0.114	0.227	0.058	0.175	-	-
Dining	0.024	0.122	0.037	0.144	0.019	0.111	-	-
Bedroom	0.020	0.113	0.031	0.134	0.015	0.103	-	-
Toilet	0.018	0.108	0.027	0.127	0.013	0.098	-	-
Kitchen	0.095	0.212	0.145	0.250	0.073	0.192	-	-
Case (c)*								
Living	0.137	0.245	0.241	0.306	0.096	0.215	-	-

- The difference between Case (b) and Case (c) is the double height roof of the Living room as shown in figure 9. Hence, in Case (c), other values remain the same as Case (b).

It is found from table 3, that the minimum areas of window inlet during heating period for *Case (a)* with wind, required for Living room, Dining room, Bedroom, Toilet, Kitchen are 0.085 m^2, 0.027 m^2, 0.023 m^2, 0.023 m^2, 0.108 m^2 respectively, and 0.164 $m^{2,}$ 0.053 m^2, 0.044 m^2, 0.044 m^2, 0.208 m^2 respectively without wind. Side lengths of the square cross-sectional duct during heating period for *Case (a)* with wind, required for Living room, Dining room, Bedroom, Toilet, Kitchen are 0.163 m, 0.103 m, 0.096 m, 0.096 m, 0.179 m respectively and 0.211 m, 0.134 m, 0.124 m, 0.124 m, 0.232 m respectively without wind.

During cooling period, it is found from the table 3, that the minimum areas of window inlet for *Case (a)* with wind, required for Living room, Dining room, Bedroom, Toilet, Kitchen are 0.057 m^2, 0.018 m^2, 0.015 m^2, 0.015 m^2, 0.072 m^2 respectively; however, for without wind case, the equation does not arrive at considerable positive values for openings and stack dimensions as shown in equation [8].

$(0.036/A_a^2) + (0.036/A_b^2) + (0.036/A_c^2) + (0.0006/s^5) = -0.6$, (without wind case) [9]

Similar is the situation for all the without wind cases in cooling period. However, area of the window and side length of the square cross-sectional duct has been calculated for other cases. Side lengths of the square cross-sectional duct during cooling period for *Case (a)* with wind, required for Living room, Dining room, Bedroom, Toilet, Kitchen are 0.140 m, 0.089 m, 0.082 m, 0.082 m, 0.153 m respectively.

Furthermore, it is observed that the minimum areas of window inlet during heating period for *Case (b)*, required for Living room, Dining room, Bedroom, Toilet, Kitchen are 0.075 m^2, 0.024 m^2, 0.020 m^2, 0.018 m^2, 0.095 m^2 respectively with wind, and 0.114 $m^{2,}$ 0.037 m^2, 0.031 m^2, 0.027 m^2, 0.145 m^2 respectively without wind. Side lengths of the square cross-sectional duct during heating period for *Case (b)*, required for Living room, Dining room, Bedroom, Toilet, Kitchen are 0.192 m, 0.122 m, 0.113 m, 0.108 m, 0.212 m respectively with wind, and 0.227 m, 0.144 m, 0.134 m, 0.127 m, 0.250 m respectively without wind.

It is found from table 3, that the minimum areas of window inlet for *Case (b)*, required for Living room, Dining room, Bedroom, Toilet, Kitchen are 0.058 m^2, 0.019 m^2, 0.015 m^2, 0.013 m^2, 0.073 m^2 respectively (with wind).The Side lengths of the square cross-sectional duct during cooling period for C*ase (b)* (with wind), required for Living room, Dining room, Bedroom, Toilet, Kitchen are 0.175 m, 0.111 m, 0.103 m, 0.098 m, 0.192 m respectively. For *Case (c)*, the dimensions would be same as that of *Case (b)* except for Living room. The minimum area of window inlet and Side length of the square cross-sectional duct during heating period for *Case (c)*, required for Living room are 0.137 m^2 and 0.245 m respectively with wind, and 0.241 m^2 and 0.306 m respectively without wind.

During cooling period, it is found from table 3, that the minimum areas of window inlet and Side length of the square cross-sectional duct for Case (c), required for Living room are 0.096 m^2 and 0.215 m respectively with wind.

The Areas of the window inlet and side lengths of square cross-sectional duct, of all the functions during heating period without wind, are observed to be maximum of all the values obtained for different cases. Hence, those dimensions can be considered for the window inlet and square duct for efficient PSV.

V. DISCUSSION

The doors and windows are generally closed in the composite climatic zone due to hot and cold winds outside. Hence PSV systems helps provide better air quality inside the residence. Besides this, the temperature goes up to 47 C during summer. The PSV systems would play a major role to operate number of air changes required as per standards given in NBC 2005. It is also the same case at times of winter, where Delhi region experiences 2^o C to 4^o C ambient air temperature. It is more essential for row type attached residential units where fresh air can be drawn from one side only. So, the results arrived above may be utilized to have quality environment in the buildings without using the conventional energy.

A few building typologies were selected with an assumption of 100 m^2 of floor area and 300 m^3 of volume to size the opening with due consideration to the PSV system as elaborated for residential building unit. The table 4 shows the ACHs as per NBC 2005 and their respective volumetric air flow rates in m^3/s. And table 5 shows the sizes of the windows inlets and side length of square cross- sectional ducts of the assumed typologies during cooling period with wind.

The same can be studied with respect to the solar thermal model with regards to non-steady state indoor air temperatures for varying thermal properties of the building components such as wall, roof, floor and fenestrations as Isothermal mass.

TABLE 4: VOLUMETRIC AIR FLOW RATE (Q) IN RELATION TO VOLUME AND RATE OF AIR CIRCULATION FOR DIFFERENT TYPOLOGIES

S. no.	Room	Volume in m^3	Rate of Air circulation in ACH (NBC 2005)	Volumetric air flow rate (Q) in m^3/s
1	Assembly halls	300	6	0.5
2	Banks/building societies	300	6	0.5

3	**Boiler rooms**	300	22.5	1.87
4	**Dye works**	300	25	2.08
5	**Garages**	300	7	0.58
6	**Gymnasium**	300	6 minimum	0.5
7	**Libraries**	300	4	0.33
8	**Restaurants**	300	10	0.83
9	**Shops and supermarkets**	300	11.5	0.96
10	**Welding shops**	300	22.5	1.87

TABLE 5: SHOWING RESULTS OF SIZE OPENINGS AND DUCT DIMENSIONS FOR SELECTED TYPOLOGIES

Area / length – sizing for varying activity spaces	**With wind case**	
	Min. area of the window (in sq. m)	Side length of a square cross-sectional duct (s) in m
Assembly rooms	0.190	0.226
Banks/building societies	0.190	0.226
Boiler rooms	0.711	0.383
Dye works	0.791	0.400
Garages	0.221	0.240
Gymnasium	0.190	0.226
Libraries	0.126	0.192
Restaurants	0.316	0.277
Shops and supermarkets	0.364	0.293
Welding shops	0.711	0.383

VI. CONCLUSION

The architectural design of buildings has to consider occupant health, air quality, comfort level, removal of odors etc. It requires adequate understanding buoyancy driven ventilation airflow which dilutes, displaces or eliminates pollutants within the occupied space. This aspect is essential and crucial for row type plotted development where two sides of the plot share common walls with the adjacent buildings forcing the owner or occupant to draw ventilation from front and rear side generally. PSV works effectively as a solution for these issues for better thermal and living conditions, without deviating from the overall space utilization, movement of occupants and furniture layout. Moreover, PSV will function naturally, economically and conserves energy.

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